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DECONTAMINATION TECHNIQUES FOR LUNAR ORBITING SPACECRAFT

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Prime objectives of present bioscience programs are the determination of location, origin, nature, and level of development of extraterrestrial life. To reduce confusion as to the origin of micro-organisms found in this search, it is extremely important that other planets not be contaminated with earthly organisms. Toward this end it is required that all lunar orbiters and/or potential landers be made biologically clean, that is, that the number of viable organisms be reduced to the lowest level possible. However, because of the harsh environment of the moon, it is assumed that any contamination of the lunar surface by a spacecraft will remain localized and will not propagate significantly. On this basis it was determined by the Office of Planetary Quarantine, NASA Headquarters, that complete sterilization of spacecraft would not be necessary for lunar missions. However, they do require that such spacecraft be biologically decontaminated to assure a low level of viable organisms at time of launch.

The mission of the several Anchored Interplanetary Monitoring Platform (AIMP) spacecraft is scientific investigation in the vicinity of the moon. It was therefore necessary to develop decontamination techniques for this series of spacecraft that would be compatible with sound engineering practice. Before such a decontamination program could begin, a test program was needed to determine the compatibility of spacecraft components and hardware with decontaminating chemical solutions and/or sterilization environments.

For the purpose of this paper, decontamination is defined as the killing and removal of the greatest number possible of viable micro-organisms which are capable of independent existence, and the removal of all other residuals such as fungi, solder spatter, flux, and other waste materials, which might serve as nutrients to support microbial life. Those components which could withstand a sterilization environment without degrading system reliability were sterilized. In all other cases, decontamination included whatever degree of sterilization of surface areas that could be achieved.

This paper describes briefly the decontamination techniques developed, the decontamination solutions applied, the methods employed for recovering viable organisms, the spacecraft assembly environment, and the overall results of the decontamination effort.

Figure #1 is a view of the AIMP spacecraft structure and depicts the general location of the electronic instrument modules in the structure.

Two methods of recovering viable organisms from the spacecraft surfaces were employed. One method employed control strips with detachable coupons. Figure #2 shows such a control strip affixed to a circuit module frame.

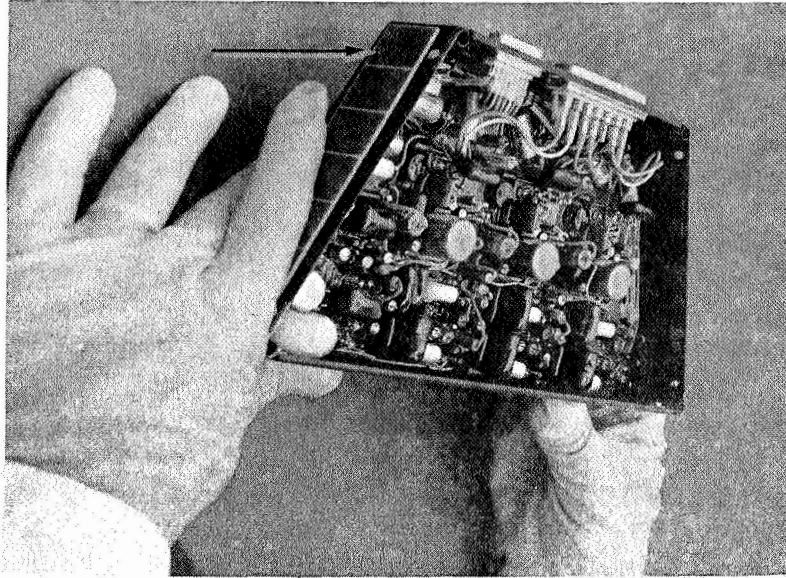


Figure 1

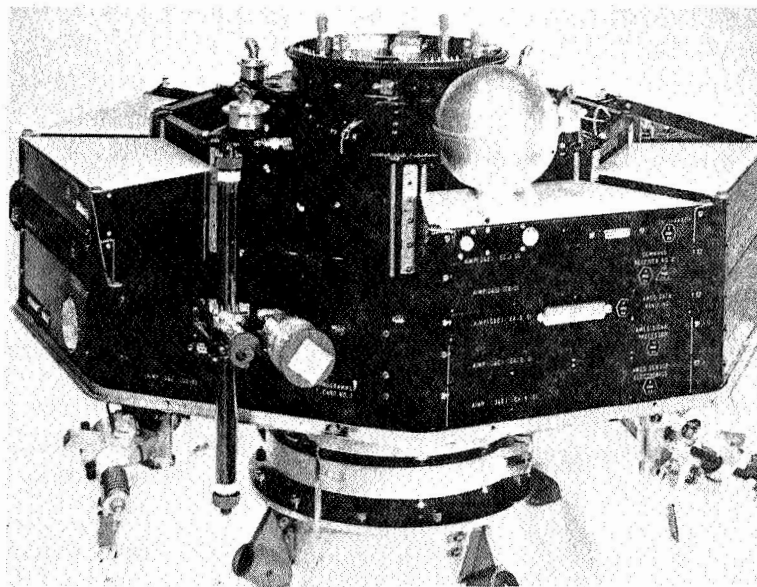


Figure 2

The strips were affixed to each module frame in a similar manner, so located as to compel the technician to touch the control strip each time he handled the module, thus creating the worst condition for contamination. The prime purpose of the control strip was to prove the effectiveness of decontamination and allow for a practical method of assaying, first, the contamination level on components prior to decontamination, and second, the probable level of viable organisms remaining on components after decontamination at each stage of occlusion by the attachments or by the conformal coating and/or

encapsulating compound. These control strips were fabricated from the same material as the printed circuit board and in such a manner as to yield five easily removed coupons. Coupons were placed into a wash bottle containing 15 ml of a 1% solution of sterile peptone. Wash bottles were then shaken with a wrist action motion for 5 minutes before transferring aliquots to pour plates. Two pour plates were so prepared, each containing a 5 ml aliquot of the contaminated wash solution. In addition, pour plates were prepared using 20 ml each of sterile tryptic soy agar as the nutrient. All of the plates were incubated at 32°C for a period of 72 hours and then plate counts were made.

The second method of recovering viable organisms employed sterile swabs and templates to sample surface areas prior to their occlusion by attachments. After swabbing of the appropriate surface, each swab was placed in a tube containing 10 ml of sterile distilled water and mechanically shaken for 5 minutes. After shaking, 4 ml aliquots were plated in duplicate and colony counts made. Figure #3 shows such a recovery operation.

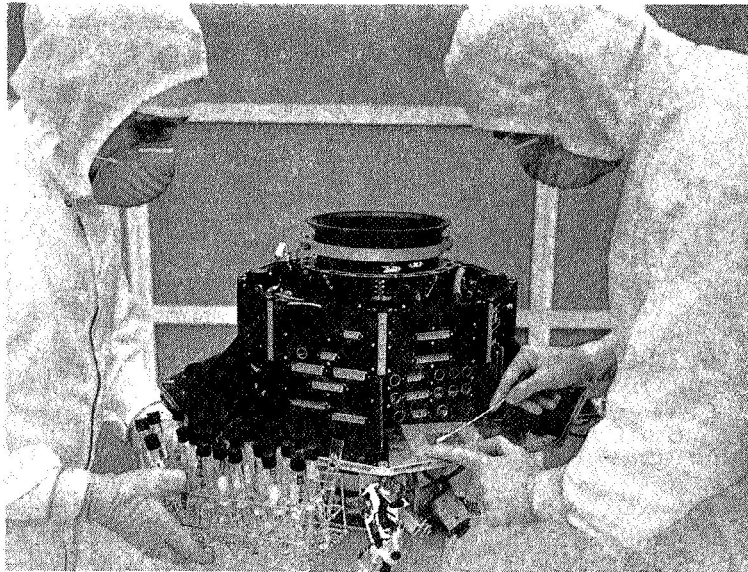
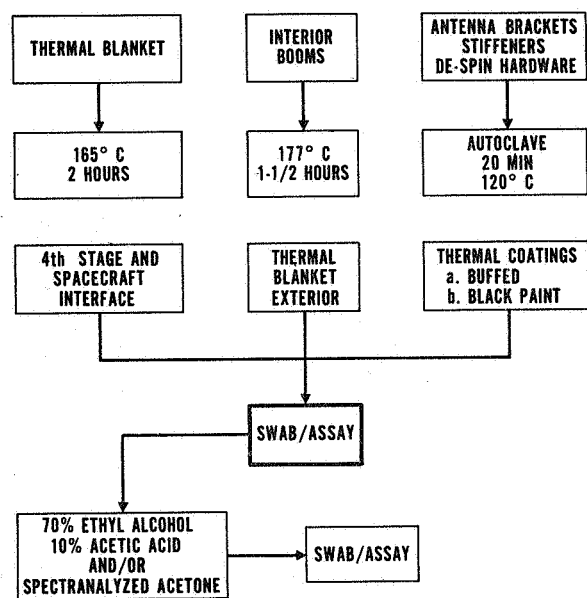
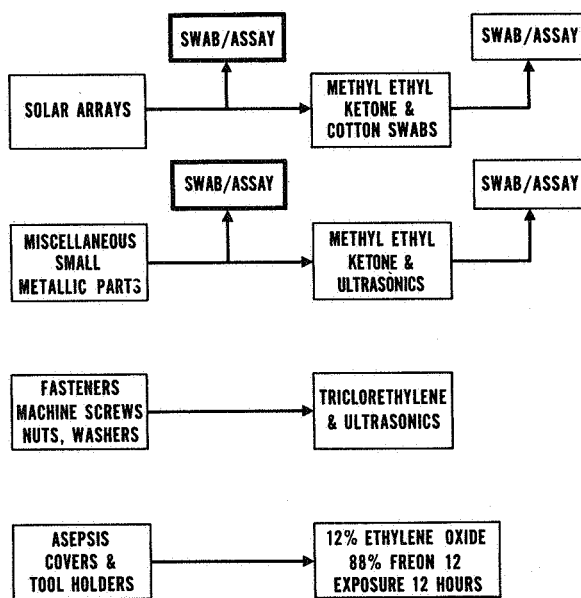
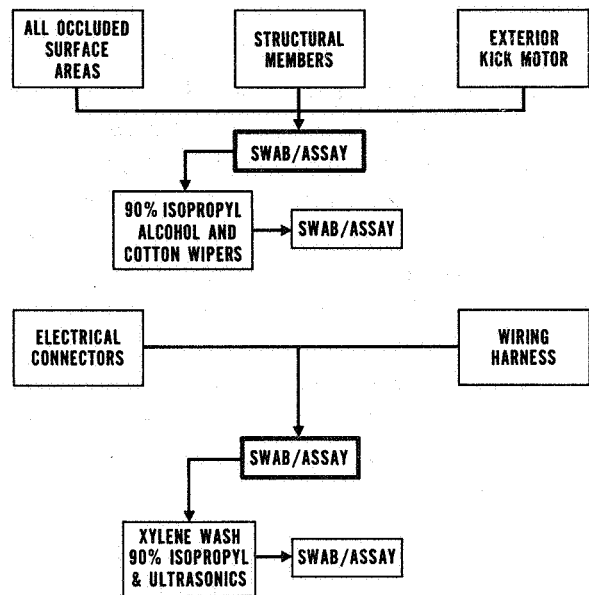
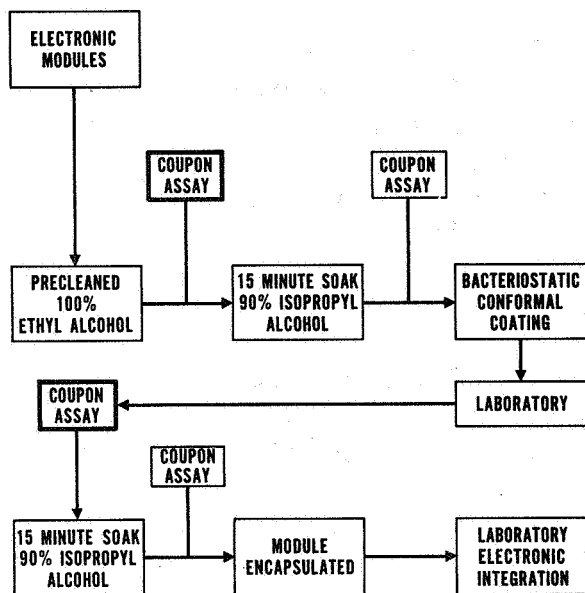
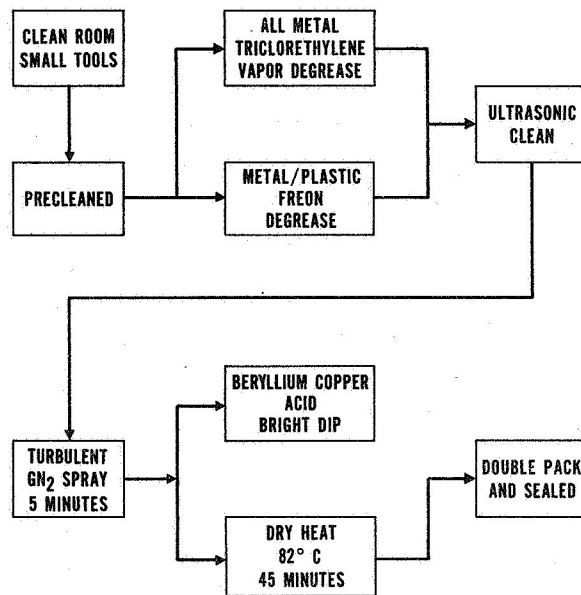


Figure 3

The following figures depict the areas decontaminated with a particular solution, the manner of decontamination and/or sterilization, and the method of recovering viable microorganisms.





The AIMP-D spacecraft was assembled in controlled work areas where the final assembly, tests, decontamination and bio-assaying were conducted under asepsis conditions in Class 100 laminarflow clean rooms. A Class 100 clean room designation implies an environment that contains no more than 100 particles per cubic foot .5 micron and larger.

Figure #4 is a view taken in the bio-clean area of the clean room complex during final decontamination of the interior of the spacecraft and assembly. The technician is

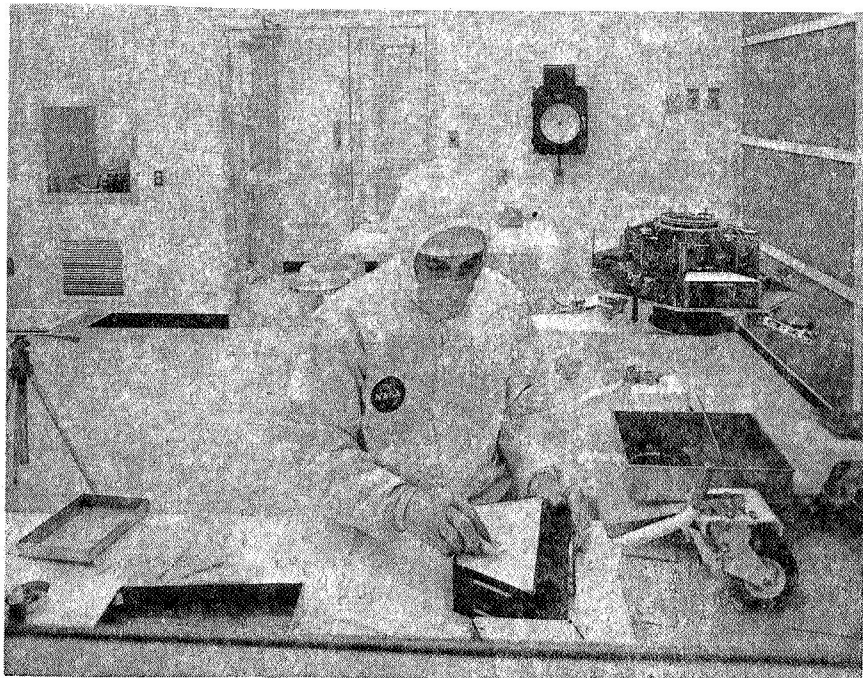


Figure 4

decontaminating the surface areas of an electronic circuit module prior to final assembly in the spacecraft structure. All such surface areas were sampled with sterile swabs prior to and after decontamination in order to determine contamination levels. The spacecraft was placed on a dolly that was previously decontaminated and remained approximately 1 foot from the face of the air inlet filter during final decontamination and/or assembly. The personnel remained downstream of the spacecraft at all times. Tools used in the assembly of spacecraft were first decontaminated and/or sterilized and sealed in plastic envelopes. All personnel in the bio-clean area wore lint-free clean-room garments that were first sterilized and treated to eliminate static electricity. They also wore booties, hoods, face masks, and disposable gloves.

On the basis of the microbial records of typical sampled surface areas, the number and size of these areas, component manufacturing methods, and environment control after decontamination, the Office of Planetary Quarantine, NASA Headquarters, determined that the orbiting AIMP-D spacecraft contained no more than 4.04×10^6 viable organisms prior to decontamination and 1.5×10^5 organisms after decontamination. An additional reduction in numbers of viable micro-organisms had occurred during the 45 day period between initial decontamination and launch as a result of natural die-off; this places the estimated total at 1.5×10^4 organisms. Assuming a successful orbit with a life expectancy of 180 days and 240 temperature cycle changes between -45°C and $+50^\circ\text{C}$ in an ultrahigh vacuum, it was determined by the Office of Planetary Quarantine that further die-off between launch and lunar impact would reduce the number of micro-organisms available for release on the lunar surface to an estimated 1×10^3 sporulative micro-organisms.

TOTAL AREA OF SPACECRAFT 526 SQ. FT.	
CONDITION	VIABLE MICRO-ORGANISMS
Contaminated	4.04×10^6
Decontaminated	1.5×10^5
Natural die-off 45 days	1.5×10^4
Assumed 180 days life orbit at -45° $+50^\circ\text{C}$ 240 temperature cycles	1.5×10^3